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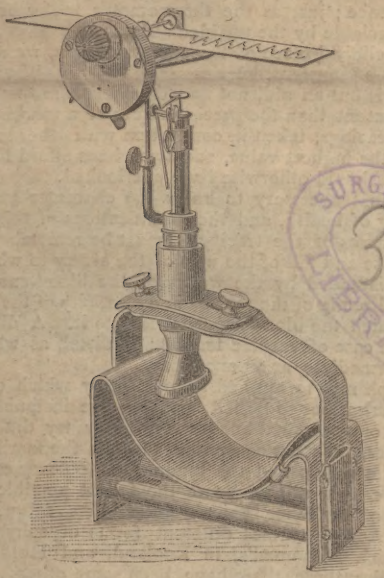

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THE CLINICAL USE OF THE SPHYGMOGRAPH.

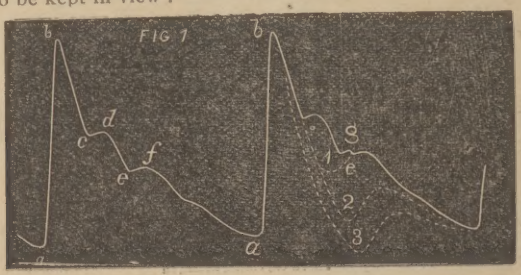
(Read before the Richmond County Medical Society, July 11, 1877, by ALFRED L. CARROLL, M. D., President of the Society.)

The importance of instrumental aids in physical diagnosis consists in their giving us a registrable measurement of the degree of departure from a known standard of healthy action. Without them the information gained by the best educated senses is to a great extent guesswork. We can easily, by touch alone, ascertain that a patient has a "high fever," or is "a little feverish," but the thermometer only can tell us the amount and portent of the pyrexia. So, with regard to signs derived from the circulatory apparatus, the practised finger can detect the marked peculiarities of a pulse that is "hard," or "soft," or "quick," or "wiry," or "irregular;" but as to the quantitative estimation of these and other deviations it teaches little. Here the sphygmograph comes to our assistance, giving its visible delineation of the phenomena which we partly know, and showing us others which we could not discover in its absence; just as the thermometer indicates minor alterations of temperature inappreciable by the unaided senses.

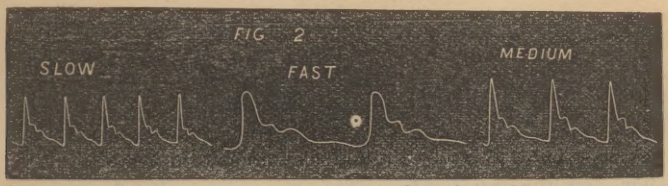
To find the true clinical place of the sphygmograph, we must guard against an over-estimate of its pretensions, bearing in mind that, like other instruments of medical inquiry, it is but an aid, not an all-sufficient means of diagnosis; that it records rather the extent than the precise nature of a morbid process. But, with this limitation, its tracings, taken in connection with other sources of information, will often prove of the highest value, and sometimes afford the earliest indications of disease which we should otherwise have overlooked.

It is, of course, first necessary to know the character and significance of the typical pulse-tracing of health, and the modifications of this under physiological conditions. The curves of the tracing, it must be remembered, represent simply the perpendicular rise and fall of the wall of the artery to which the instrument is applied, as it is distended by the waves of the blood-current. These curves, therefore, teach us directly of the tension and elasticity of the artery, and indirectly of the force with which the blood is propelled into it. A disturbing agency may be central, as in the case of cardiac lesions; or distal, as when the arterioles are contracted; or intermediate, as an aneurism.

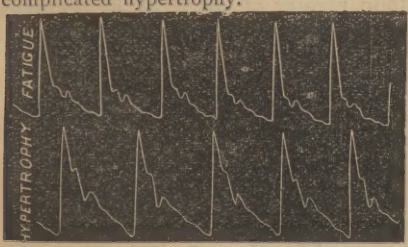
The sphygmograph may be applied to any artery which comes near enough to the surface for its pulsations to be felt, and in some instances, where it is desired to locate a thoracic or abdominal aneurism, we may try different situations; but, for ordinary purposes, the most convenient place is the familiar fossa between the styloid process of the radius and the tendon of the flexor carpi radialis, where a little practice will enable us to procure the fullest possible development of the curves in any given case. Since Marey's original mechanism, and its modifications by Sanderson and Anstie, several different forms of sphygmograph have been devised, among which Mahomed's, in England, and Holden's, in America, are well known. Besides these, there have been some others which I have had no opportunity of testing, all, however, with the exception, I believe, of one inchoate invention a few years ago, depending for their graphic power upon a spring-pad pressing on the artery. By far the most sensitive and satisfactory instrument which I have seen is one constructed by Dr. E. A. Pond of Rutland, Vermont, in which the arterial waves are transmitted through a film of India-rubber to a column of water bearing a float, the rise and fall of which move a lightly-balanced lever terminating in a flail-jointed needle, whose point, resting on a smoked slip of mica, records the pulse-tracing. By this means resistance and friction are reduced to a minimum. The subjoined enlarged tracing of a healthy pulse (Fig. 1) shows the main points to be kept in view:



From *a* to *b* is the quick rise of the artery, caused by the first wave from the contraction of the ventricle, *b* being the point of greatest distention of the artery; from *b* to *c* is the recontraction of the elastic arterial wall, vibrating for an instant so as to overcome the impetus of the current; from *c* to *d* is a secondary redistention of the vessel by the wave following this momentary check; from *d* to *e* is the continued contraction of the artery down to the closure of the aortic valves, at *e*, the shock of which is followed by a fresh rebound of the blood-column at *f*. From *a* to *e*, therefore, we have the phenomena of the heart's systole; from *e* to *a* again, those of the diastole; or, as regards the vessel under observation, from *a* to *b* is the sudden afflux of blood into the artery; from *b* to the end of the tracing is the gradual efflux of blood from it. Where the artery is elastic and the tension low, several subordinate waves are often shown in the diastolic line from *e* to *a*, and occasionally an interpolated wave (*g*) is seen at the aortic closure where there is no evidence of valvular disorder. In many pathological, and in some physiological, conditions, we find what is known as "dicrotism," characterized by obliteration of the first secondary wave and deepening of the "aortic notch;" the dotted lines 1, 2, 3, indicate respectively "subdicrotism," "full dicrotism," and "hyperdicrotism," the aortic notch in the latter falling below the general base-line of the tracing. Knowing the significance of these different parts of the normal pulse-trace, we are better prepared to appreciate the import of any deviations from them. It is to be remembered, in the first place, that the rate of speed at which the record-bearing slip is moved will considerably modify the form of the curves. This is shown in Fig. 2, where the same pulse is traced with the slip moving at "slow," "fast," and "medium" rate.

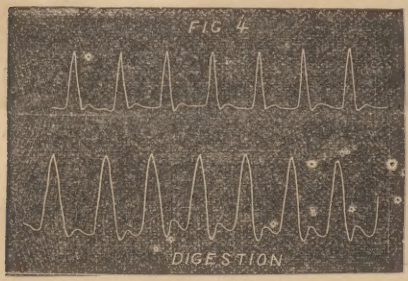


The amplitude of the tracing, or the height of the line of ascent, is influenced by the amount of pressure brought to bear upon the artery. The pressure requisite to develop the amplest trace in any given instance should be noted as indicating the resistance of the pulse. The average pressure to be used is stated by Weiss to be 300 grammes (10.6 oz. av.); Sanderson estimates it for the most resistant pulses at 400 grammes (14.1 oz.). The latter author was, I believe, the first to formulate the clinical indications afforded by this means, pointing out that in fever, if low pressure suffice to bring out the maximum trace, stimulants will be useful; while, if as much as 200 grammes (7.05 oz.) be required, stimulation is needless. On the scale of Pond's instrument each division represents fifteen grammes, or a little more than half an ounce (thirty indicating a pound); but, as the elasticity of the wrist-clasp has also to be overcome, the apparent pressure must be increased by some ounces in most cases. Aside from the pressure, however, the height of the "systolic apex" (which, as we have seen, is the point of equilibrium between cardiac impulse and arterial distensibility) is affected by two opposite sets of causes. Thus, it may be increased either by augmented force of the ventricular contraction, as in hypertrophy, or by diminished tonicity of the arterial walls, as in advancing age (without senile degeneration), or simple fatigue. The similarity and the distinction between these conditions are illustrated in Fig. 3, the upper tracing being that of fatigue in a healthy man, the lower, that of uncomplicated hypertrophy.

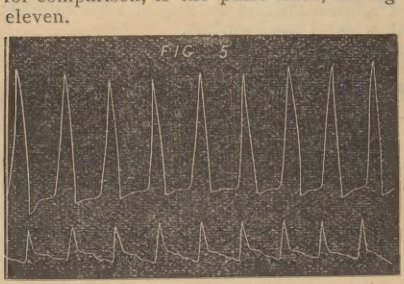


The pulse of fatigue, it will be noticed, is marked by a high systolic ascent and an abrupt fall, the first wave of rebound being close to the aortic notch, and the tracing generally showing "low tension." In the pulse of hypertrophy, the line of descent shows no signs of diminished arterial resistance, but only an increased *vis a tergo*, the preaortic wave being high up, and the whole character of the tracing an exaggeration of that of health.

The position of the preaortic wave is determined, on the one hand, by the ventricular force; on the other, by the fullness of the artery. In the typical tracing of robust health, it is situated at about the junction of the upper and middle thirds of the line of descent. In proportion as the cardiac impetus is enfeebled (producing a shorter line of ascent), or the tension of the artery increased, this wave will approach nearer the systolic apex; while an increase of the systolic ascent, or a lessening of the volume of blood in the vessel, will cause a relative or an actual lowering of the wave, or even its total obliteration. This is commonly seen after a hearty meal, when, a greater amount of blood being attracted to the digestive organs, the peripheral vessels are partially emptied, giving a "dicrotic" tracing (i. e., an unbroken descent to the aortic notch) with very low tension. Fig. 4 shows the radial pulse of digestion, the upper tracing being from the same subject as in Fig. 2, the lower from a vigorous and athletic man; in both, and especially in the latter, the fall of the aortic notch is hyperdicrotous.

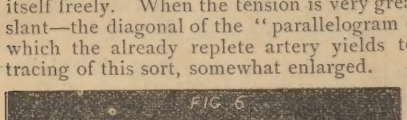


We have learned, thus far, that the characters of a healthy pulse-trace may vary in rest or fatigue, before or after a meal; and these circumstances are to be considered in the examination of any individual case. As a rule, the highest rise and deepest fall will be found in the after-dinner pulse of an elderly person of sedentary habits, while the most compact and gradual-descented tracing belongs to vigorous, fasting youth. Fig. 5 is a tracing taken from a gentleman past seventy, with slight functional irregularity, but no actual lesion of heart or vessels. Below it, for comparison, is the pulse-trace, during digestion, of an active, healthy boy of eleven.



The condition of dicrotism is also induced by heat, emotion, or alcohol taken to the commencement of narcotism; and it affords a measure of the severity of febrile action, subdicrotism accompanying mild pyrexia, and hyperdicrotism warranting a grave prognosis, and pointing to the need of stimulants, which, in such case, manifest their beneficial action by raising the aortic notch to a higher level.

Among the pathological indications given by the sphygmograph, one of the most important is the amount of tension, which is shown chiefly by the character of the line of descent. The greater the tension of the artery, the more does this line of descent approach a convex form, and the less marked are its "notches," especially the preaortic one. The amplitude of the tracing is less, even though the impulse of the heart be stronger, because the obstruction to the efflux of blood from the artery prevents it from falling to as low a base-line as when the vessel can empty itself freely. When the tension is very great, the line of ascent will have a decided slant—the diagonal of the "parallelogram of forces"—owing to the slowness with which the already replete artery yields to the incoming wave. Fig. 6 shows a tracing of this sort, somewhat enlarged.

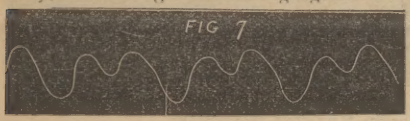


High tension is indicative of a distal impediment to the egress of blood from the artery, and for its cause we must look to the capillary circulation in most cases. Whether from the "hyaline-fibroid" thickening described by Gull and Sutton, or from the muscular hypertrophy of the arterioles demonstrated by George Johnson, or from spasmodic contraction of these latter, we shall have increased fullness of the arterial trunks, either permanent or temporary. Thus, tension is for the time heightened in angina pectoris, spasmodic asthma, probably in the initial stage of epilepsy; in blood-poisonings of various kinds, whether in the zymotic exanthemata, lithæmia, alcoholism, or plumbism; while in renal disease Dr. Mahomed

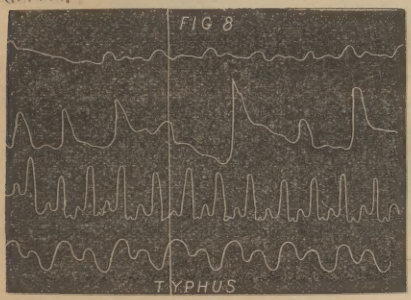
has pointed out the early diagnostic value of augmented tension during what he terms the "prealbuminuric" stage, the transudation of albumen being, according to his view, the result of a farther and extreme tension of the capillaries.

As regards valvular cardiac lesions, the brief time at our disposal will force me to deal with them cursorily; and, indeed, much yet remains to be done before the sphygmograph can add greatly in this direction to the knowledge which we may derive from the stethoscope; its tracings showing us, as I have already remarked, rather the extent than the precise nature of the disorder.

In mitral regurgitation, the insufficient force of the heart's systole fails to distend the artery promptly and fully, and, accordingly, we have a feeble and more or less slanting ascent with a blunted summit instead of the sharp apex of health, deficiency or absence of the preaortic notch; and the general character of the tracing indicates that the contractile power of the artery is more than a match for the distensile action of the heart. There is, however, no uniformity in the tracings produced by this condition, and very similar curves may arise simply from functional weakness of the heart's contraction, notably, as Sanderson has shown, in the undulating pulse of typhus. Hyperdicrotism is usually present. Diagrammatically, the tracing of mitral regurgitation is represented, enlarged, in Fig. 7.

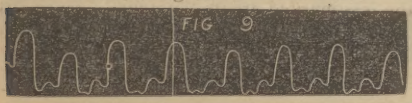


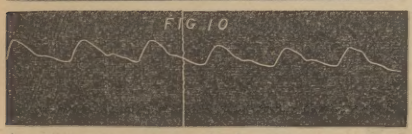
But practically there are many departures from this type, depending on the amount of ventricular hypertrophy, the resistance of the arterial walls, etc. Fig. 8 shows some of these variations, the upper tracing being copied from Da Costa; the second, from Sanderson, evidently accompanied by hypertrophy; the third is from a case of rheumatic endocarditis, which I had the opportunity of examining with Dr. C. H. King, wherein, with a marked systolic murmur at the apex, there were much debility and extremely low tension; below this, for comparison, is the pulse of typhus, taken from Sanderson.



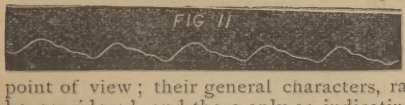
With regard to the last two examples, it will be noticed that the slip was moving in my tracing only about half as fast as in Sanderson's; an equal rate of speed would spread out the curves as in Fig. 9,

Mitral obstruction gives an oblique ascent with low tension, but the pulse-tracing is, as a rule, more regular than in mitral regurgitation; varying, however, in the more advanced stages of the disease, and indicative rather of diminished *vis a tergo* than of the specific lesion, which can be more accurately ascertained by means of auscultation. A sphygmogram of mitral obstruction, afterMarey, is given in Fig. 10.





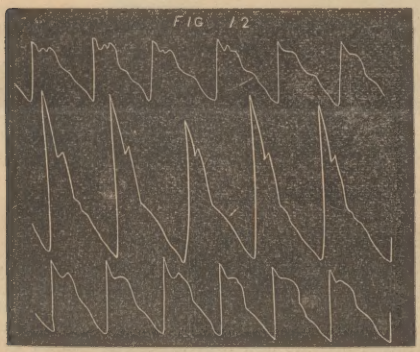
Still more marked is the obliquity of ascent in the case of aortic obstruction, which, by retarding the flow of blood into the arteries, causes a gradual instead of a sudden distention of their walls. The usual curve in this condition is shown in Fig. 11; but, as will be seen further on, it is not unlike the tracing of mere senile degeneration; indeed, a similar trace may be produced by any cause which weakens and prolongs the ventricular systole.



Be it remembered, that none of these tracings of valvular lesions are to be accepted as typical from a diagnostic point of view; their general characters, rather than their individual traits, are to be considered, and these only as indicating the extent to which the circulation is crippled. Modification may be produced by the force or feebleness of the heart's action, by the condition of the arteries, and other disturbing factors; or we may

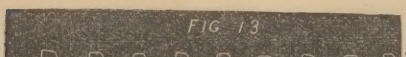
have a coincidence of more than one lesion, as when aortic obstruction leads secondarily through dilatation of the ventricle to mitral incompetence; mitral or aortic regurgitation induces compensating hypertrophy; or when at either orifice a double lesion—both obstructive and regurgitant—is established.

In fact, the only valvular disorder which gives an almost unmistakable pulse-trace is aortic regurgitation, wherein we find, as might be expected, a marked diminution, or even a total obliteration of the aortic notch (which, as has been shown, is caused by the quick closure of the aortic valves), accompanied by a sudden fall from the preaortic notch, which is usually much higher up than in health. The complete emptying of the artery during diastole gives amplitude to the trace by lowering the base-line. Occasionally a vibratile movement is seen at the preaortic notch, giving a multiple wave. This is illustrated in the upper tracing of Fig. 12, copied from Foster. The second tracing is from Sanderson, showing marked aortic regurgitation with hypertrophy. The third is my own.

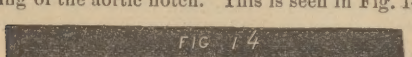


The comparative rarity of valvular lesions of the right side of the heart and the fact that their effects upon the systemic arteries must be produced by a backing up through the venous circulation, deprive their sphygmographic tracings of any diagnostic importance, the curves indicating chiefly variations of tension or diminished impulse of the left ventricle, as the difficulty at either right orifice may be regurgitant or obstructive. Tricuspid obstruction will indirectly induce heightened tension through the systemic capillaries; tricuspid insufficiency, or either form of disease at the pulmonary opening, will more or less weaken the systolic part of the pulse-trace by diminishing the quantity of blood received by the left auricle.

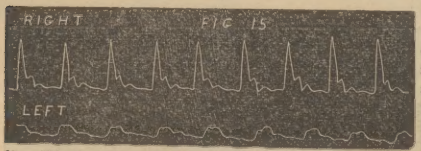
Atheroma manifests itself in a decapitation of the line of ascent, which, instead of the sharp apex of health, terminates in a horizontal plateau, as in Fig. 13.



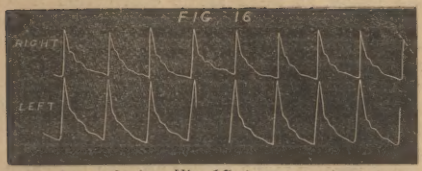
Senile degeneration of the vessels, impairing their elasticity, gives a tracing somewhat resembling that of aortic obstruction, with rounded summit, high position of the preaortic wave, and shallowing of the aortic notch. This is seen in Fig. 14.



A very practical use of the sphygmograph may be made in the diagnosis of aneurism, the pulse-trace on the distal side of an aneurismal enlargement being, of course, deprived of its normal angles and notches, and reduced, if the sac be large, to a mere undulating line. Fig. 15 shows the right and left radial tracings from a case in the Seamen's Retreat Hospital, in which rational symptoms alone led Dr. King to diagnose thoracic aneurism, the physical signs not being satisfactorily marked.



Here the sphygmogram demonstrated conclusively that the aneurism was situated at the transverse arch of the aorta, on the distal side of the innominata, but involving the origin of the left subclavian. On the other hand, in a case which I saw with my friend, Dr. W. C. Walser, where there was a pulsating tumor rising above the clavicle at the inner side of the right sterno-mastoid, and all the rational signs seemed to warrant a diagnosis of innominate aneurism, the right and left radial tracings were as in Fig. 16; proving that the enlargement was confined to the trunk of the right common carotid, which was probably longer than usual, or perhaps sprung independently from the arch of the aorta, as sometimes happens. Certainly, there is no involvement of the aorta itself, nor of the right subclavian, though the somewhat less amplitude of the right tracing (taken with the same pressure) would appear to indicate a slight mechanical compression of the latter artery. In this case the heart was greatly enlarged.



Functional disturbances and irregularities, of course, impress their modifications upon the pulse-trace, but it is seldom necessary to call in the aid of the sphygmograph for their diagnosis, except, perhaps, in an obscure case where its record may serve to exclude organic lesion. As an instance of extreme irregularity, Fig. 17 shows tracings from a case of exophthalmic goitre, which I was enabled to procure through the kindness of Dr. Walser.

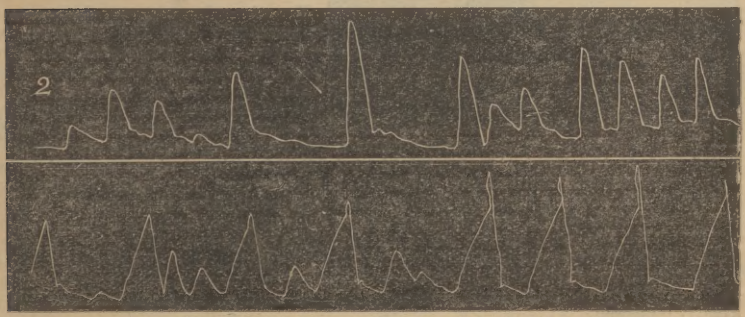
It would be easy to multiply examples of different morbid conditions, but my object has been to select the more salient and practically useful features of sphygmography, pointing out as briefly as possible the results which have been obtained thus far, and leaving to be inferred how much may yet be done by careful observation to increase the clinical value of one of the most ingenious of instruments.—*New York Medical Journal, September*, 1877.

It is a well established fact that the conditions of the circulative organs can be fully illustrated by the Sphygmograph. Degenerative disease in its earliest stage consists in structural lesions of the minute arteries, which can be ascertained by the use of the Sphygmograph. Atheromatous and senile changes, aneurism, organic valvular diseases of the heart, pericarditis, phthisis, organic and functional diseases of the brain, diseases of the kidneys, plumbic poisoning, poisoning by digitalis, rheumatism, palsy, pneumonia, typhoid fever, and intermittent fever, are those which have been most observed, and many of them can be diagnosed by the use of this instrument, and their course graphically illustrated.

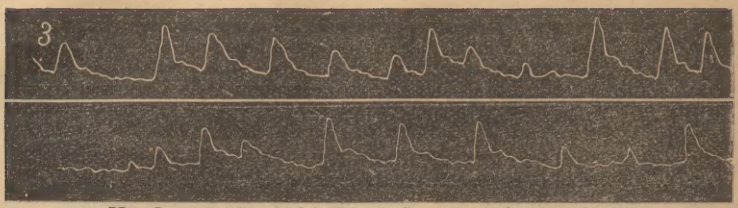
The general practitioner will find the Sphygmograph of great assistance in his daily practice, by giving him the more exact condition of his patients from day to day, in acute diseases, showing the progress of the disease and the effects of medicines and nutrition, giving him more timely notice of exhaustion and tendency to sinking, making it clear and positive how and when to stimulate. As a reference from day to day it is very valuable, giving a better history of the case than could otherwise be described. In prognosis, from the great delicacy of this instrument one can detect a fatal sinking many hours earlier than it can be felt in the pulse by the most expert and educated finger.

In nervous disorders and functional disturbances it will be found of constant assistance. Undoubtedly, by its general use, much light will ultimately be thrown on many obscure diseases.

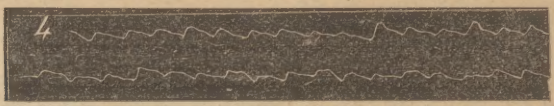
NORMAL AND IRREGULAR TRACINGS.



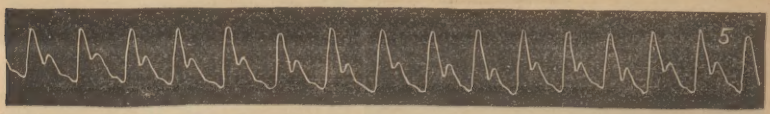
No. 2.—Ataxia of the Heart in Fever.



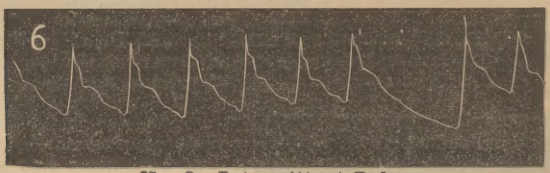
No. 3.—Ataxia of the Heart, Pericardial Adhesions.



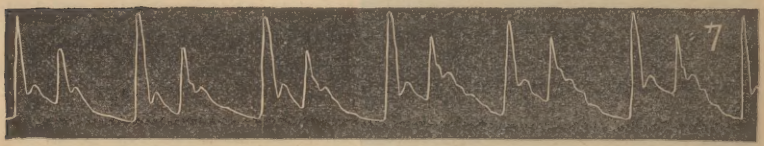
No. 4.—Just before Death. Inanition from Malignant Stricture of Œsophagus.



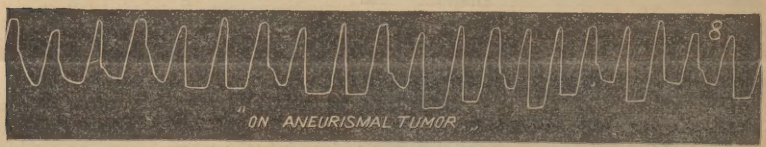
No. 5.—Robust Health, Outdoor Exercise.



No. 6.—Intermittent Pulse.



No. 7.—"Bigemini."



No. 8.—Trace from an Aneurismal Tumor.

This Sphygmograph can be used as quickly as the ordinary mode of feeling the pulse, and every difficulty heretofore existing in other instruments has been entirely obviated in this.

Its tracings are made on a smoked surface or with ink on paper.

We have made great improvements in this instrument since it was first introduced, and it is now perfect in every respect. The great difficulty experienced in the application of the Sphygmograph, is in this instrument obviated by means of a delicate spring balance, which shows the exact amount of pressuee applied to the pulse.

The connection between the float and the needle is magnetic, rendering the movements of the needle positively accurate. Also a pendulous mirror has been adopted for the use of light. The most delicate vibrations of the pulse can be thrown on a screen and enlarged to any extent desired. It will be found convenient for teachers of physiology, and of practical use to the physician. By this means the pulse can also be photographed.

Testimonials from Prominent Physicians.

12 East 28th St., New York, July 10, 1877.

Dear Sir—I have used your Sphygmograph for the last two months and find it the best that I have ever used. It is so easily adjusted that I use it *twenty times* where I would have used the other instrument once. It is easily kept in order, and I think that when the value of sphygmographic observation is more generally known *every physician will have one.*

Very truly,

T. A. McBRIDE,
Lecturer on Symptomatology, College of Physicians and Surgeons, N. Y. City.

To Dr. E. A. Pond.

Boston, April 13th, 1877.

E. A. Pond, M. D., Rutland, Vt.—*My Dear Sir*—I have yours of the 12th inst., and shall be glad to see you when you come to Boston. I have examined with great interest your improved Sphygmograph. It seems to me to meet just what is most needed in that instrument—easy adjustment, delicacy of record, and exactness in result. Yours very truly,

J. BAXTER UPHAM,
Late Physician to the Boston City Hospital, Member of the Mass. Medical Society, Fellow of the American Academy of Arts and Sciences, &c., &c.

Davis Avenue, New Brighton, Staten Island, Oct. 5, 1877.

Dear Doctor Pond—After some months of constant employment of your Sphygmograph, I am glad to testify that for ease of application and delicacy of registration it *far excels* any instrument of the kind with which I have worked.

Faithfully yours,

ALFRED L. CARROLL,
Pres. of the Richmond County Medical Society.

Dr. E. A. Pond.

1811 Spruce St., Philadelphia, May 29, 1877.

Dear Doctor—I have much pleasure in introducing Mr. Pond of Rutland, Vt,, who has a Sphygmograph devised by his father, Dr. Pond, which I regard as superior in point of delicacy and ease of manipulation to any I have ever seen.

Very truly,

WILLIAM PEPPER,
Clinical Prof. of Medicine, University of Penn.

We respectfully refer you to the following eminent physicians:

Dr. H. I. Bowditch, Boston, Member of the Society Medical Observation, Paris.

Dr. J. M. DaCosta, Philadelphia, Lecturer on Clinical Medicine and Physician to the Philadelphia Hospital.

Prof. J. W. S. Arnold, New York, Professor of Physiology, University of New York.

Prof. W. A. Hammond, New York, Professor Materia Medica and Diseases of the Mind.

Prof. Meredith Clymer, New York.

Prof. Edward G. Janeway. "

Prof. A. L. Loomis. "

Prof. E. C. Seguin, New York.

Dr. J. R. Leaming, New York City.

Dr. Egbert Guernsey, New York.

Dr. H. B. Millard, New York City.

Dr. Edgar Holden, Newark, N. J.

Dr. J. H. Baxter, Chief Medical Purveyor, U. S. Army, Washington, D. C.

Lewis A. Sayre, M. D., New York, Professor of Orthopedic Surgery, &c.

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